# RF Backplane For MTCA.4 Based Control System

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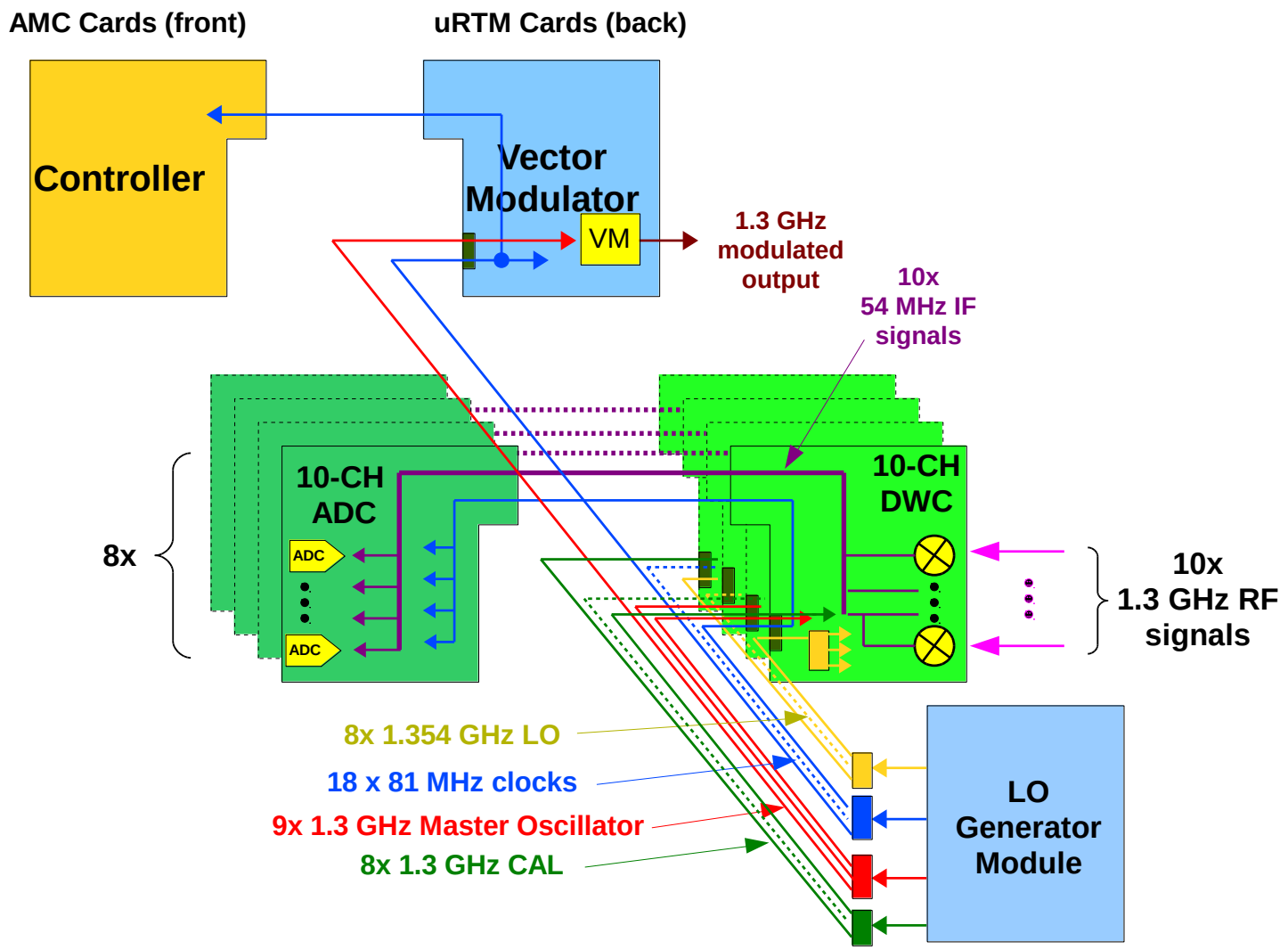
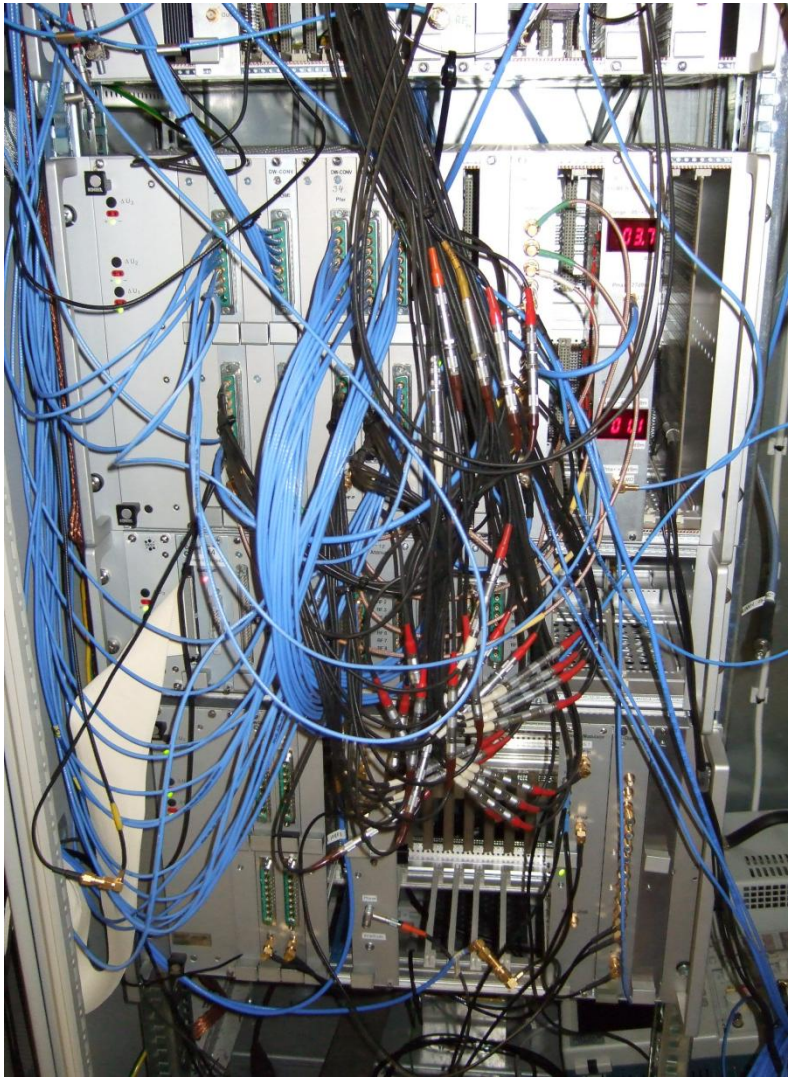
# Internal LLRF System RF Signal Distribution in Fully Equipped MTCA Crate



# In Practice Crate Surrounding Would Look Like That…

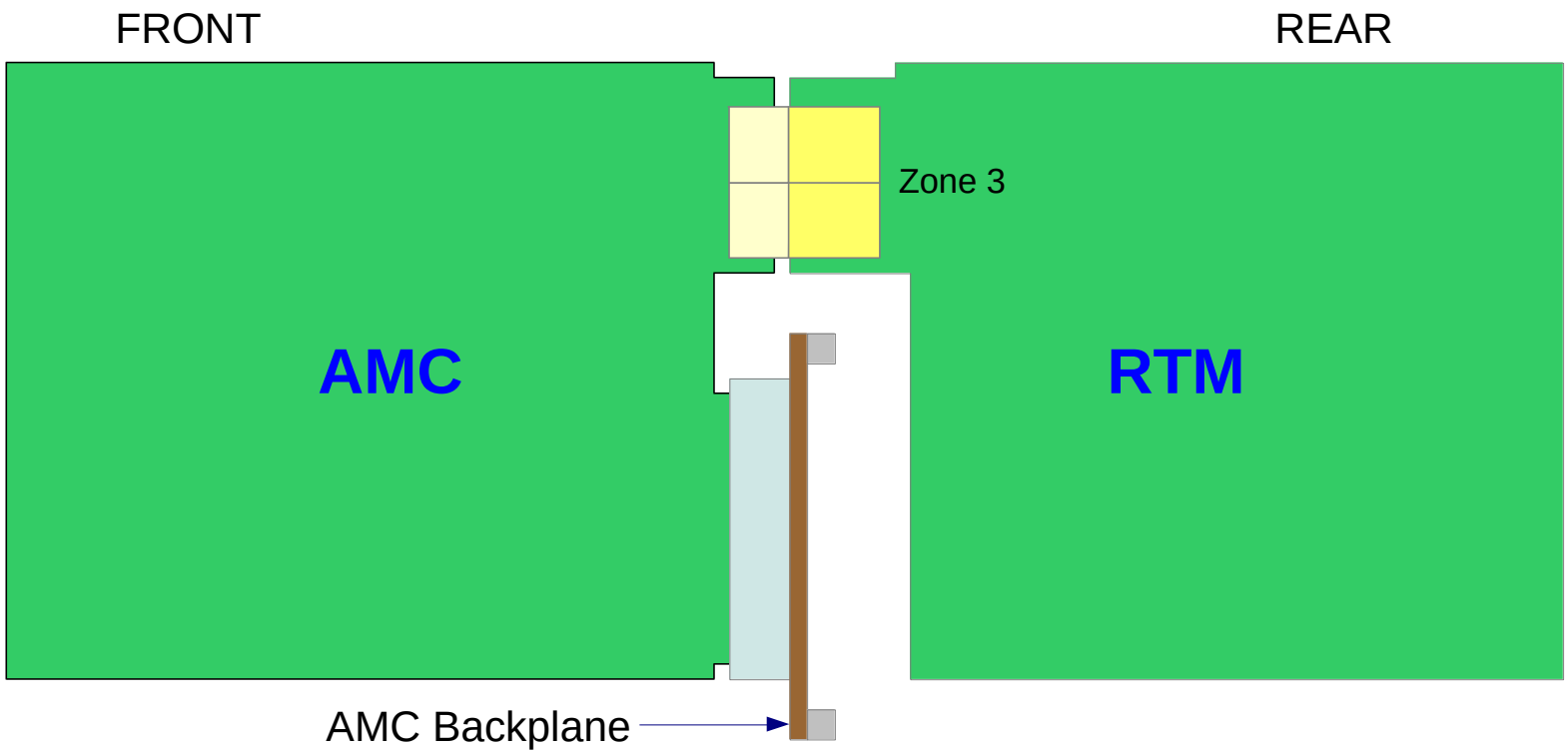
Cable management is a fundamental problem for many applications



What about hiding „internal” LLRF connections inside of the crate?

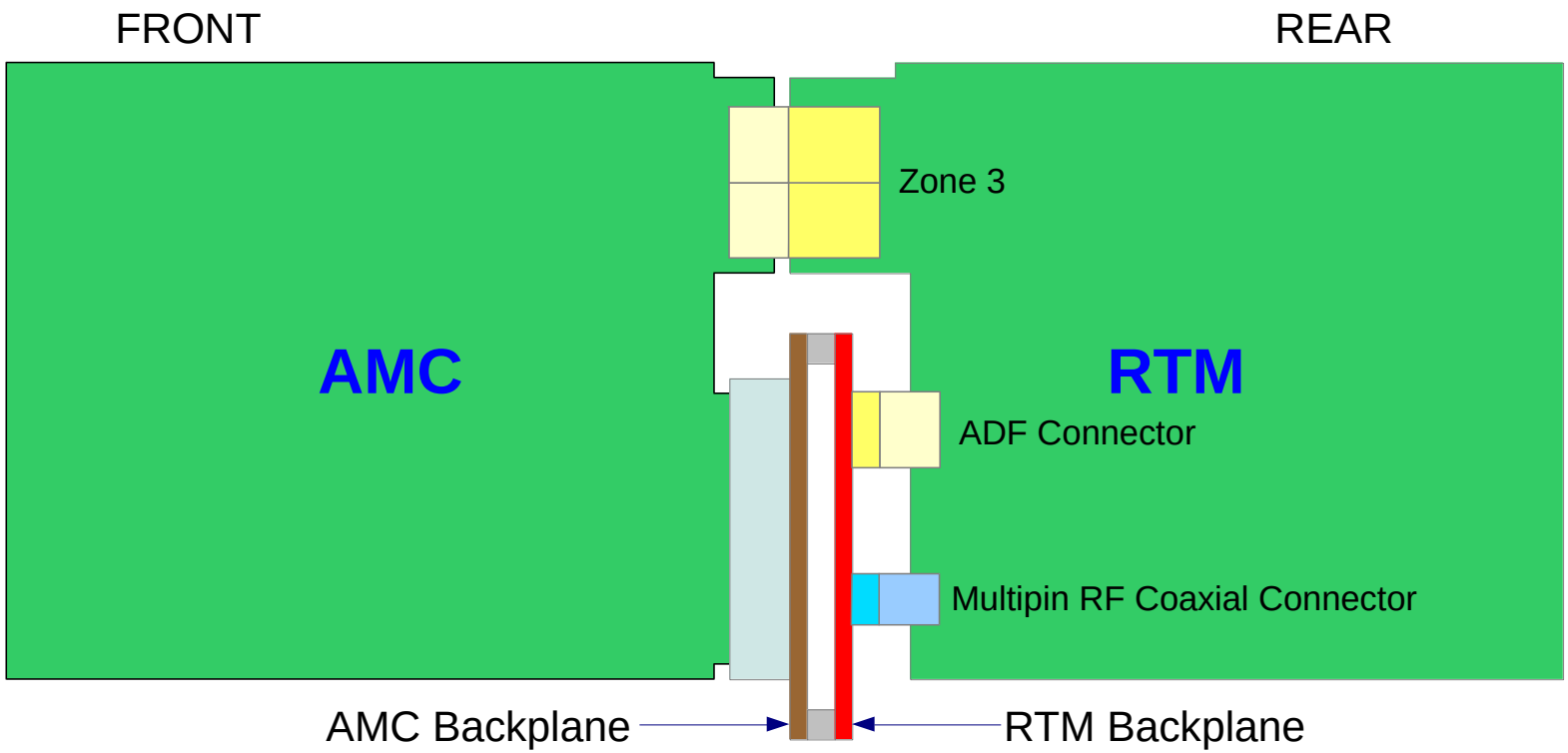
**RF Backplane Solution**

# AMC-RTM Pair – Side View



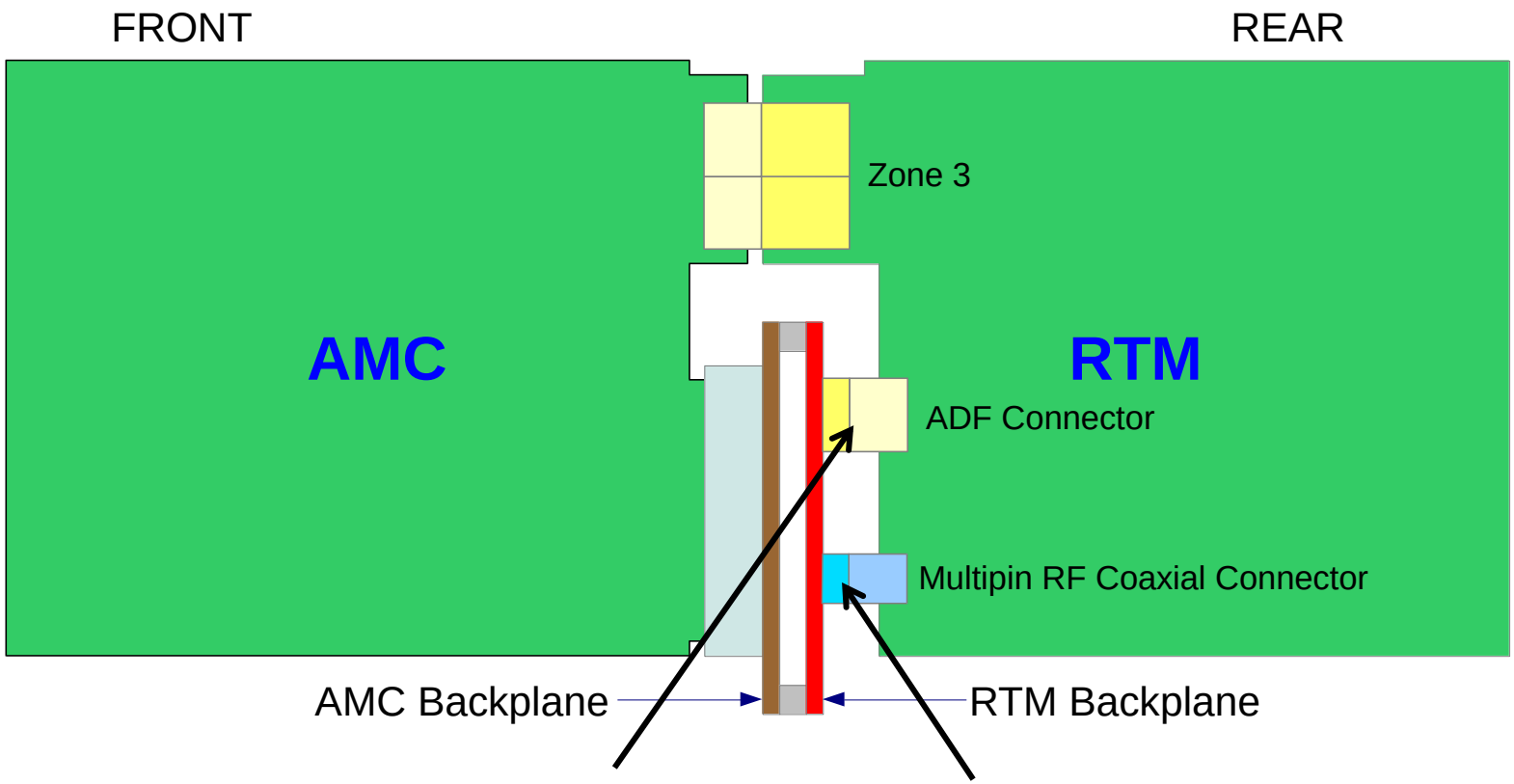
# AMC-RTM Pair – RF Backplane Location

## Abbreviation **uRFB** - **u**TCA **RF B**ackplane

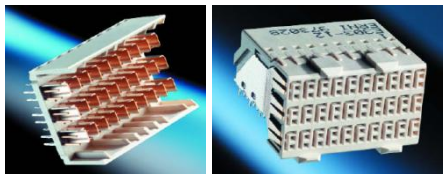


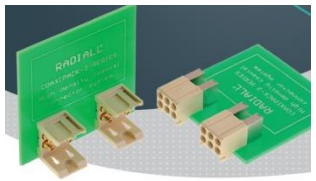
# AMC-RTM Pair – RF Backplane Connectors

## Abbreviation **uRFB** - **u**TCA **RF B**ackplane




ERMET ZD,
3x10 diff. pairs

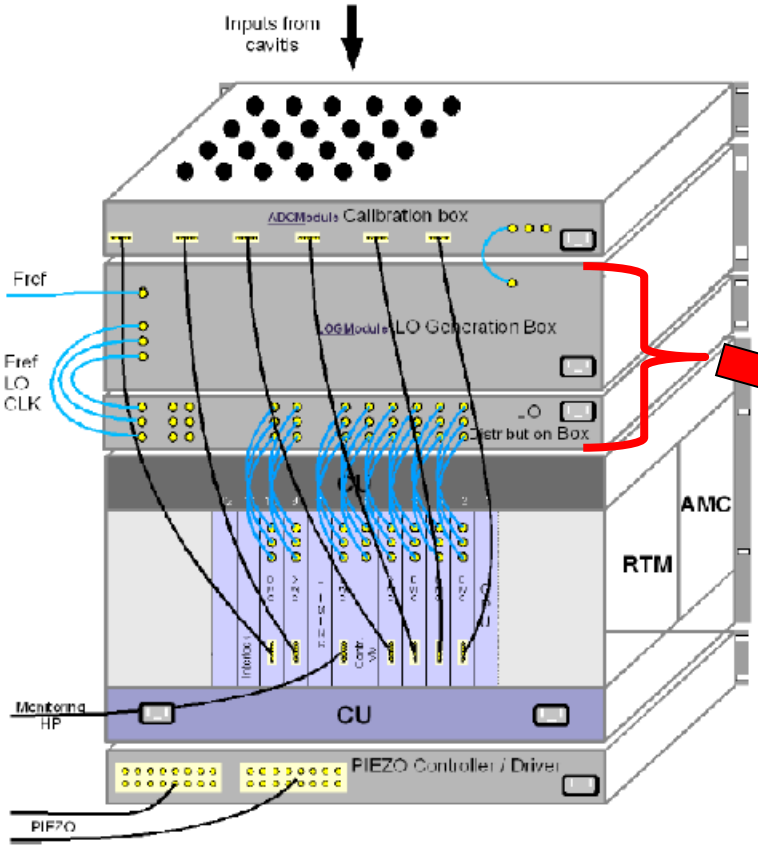




Radiall Coaxipack 2
6-pin, 6GHz RF connectors

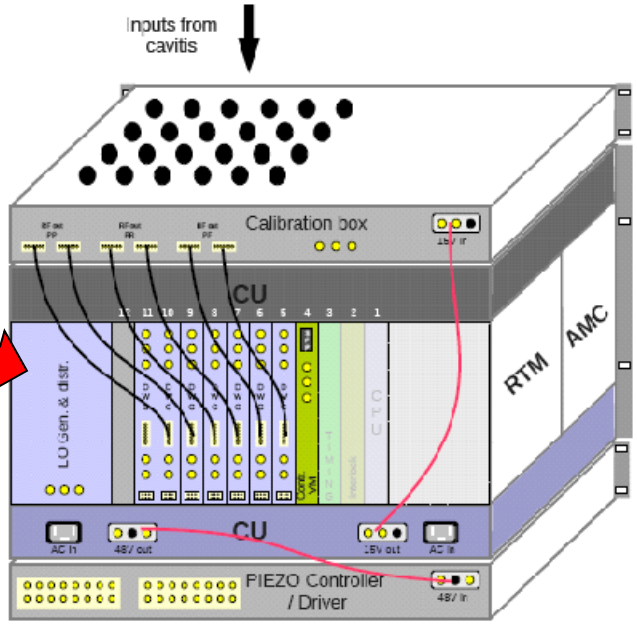
# Advantages of the RF Backplane Concept

System with signals distributed outside the crate




System with RF Backplane

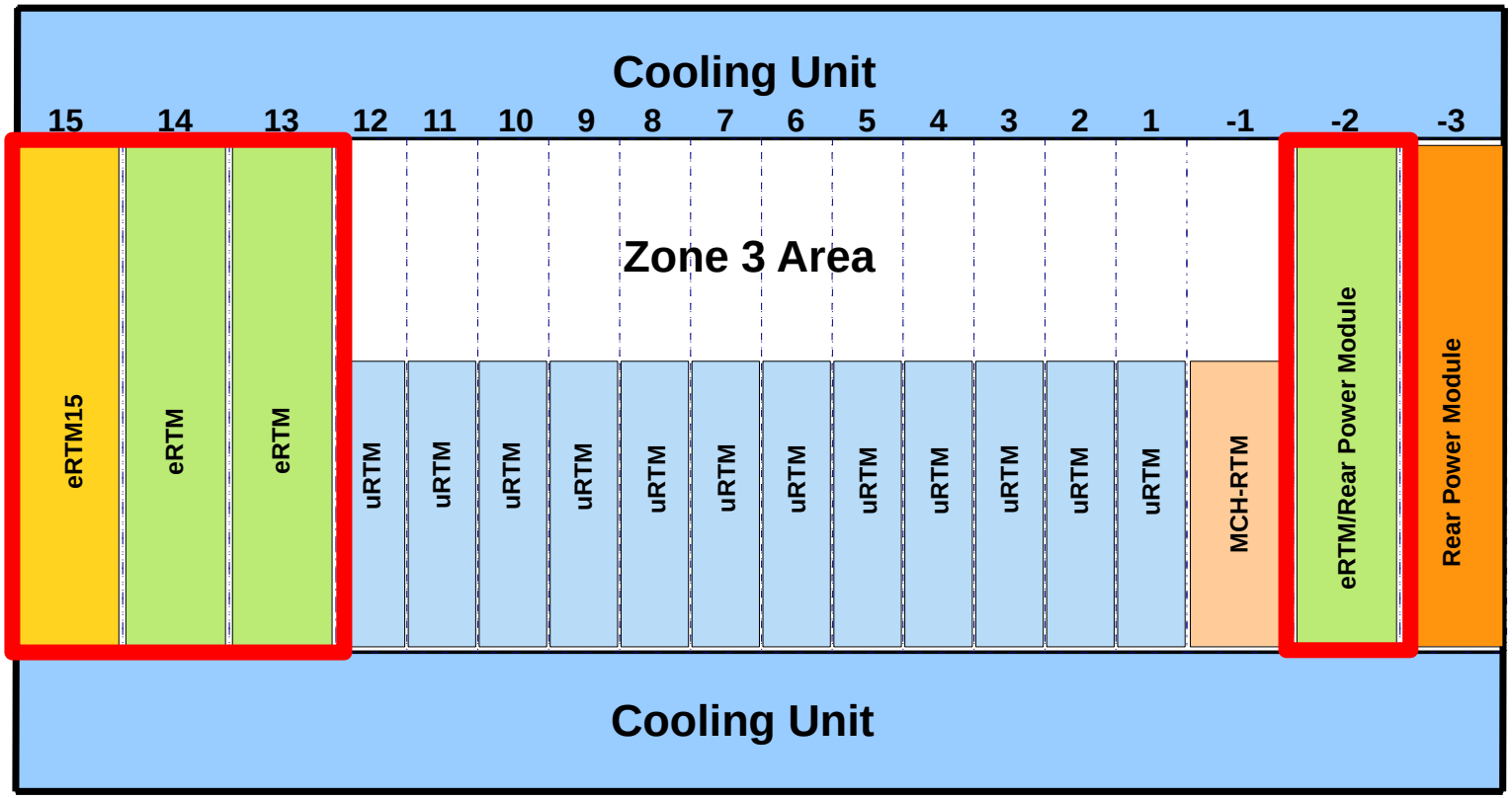
- Improved cable management
- Higher reliability
- Space reduction



# Slots, eRTMs and Rear Power Supply Modules

Rear View

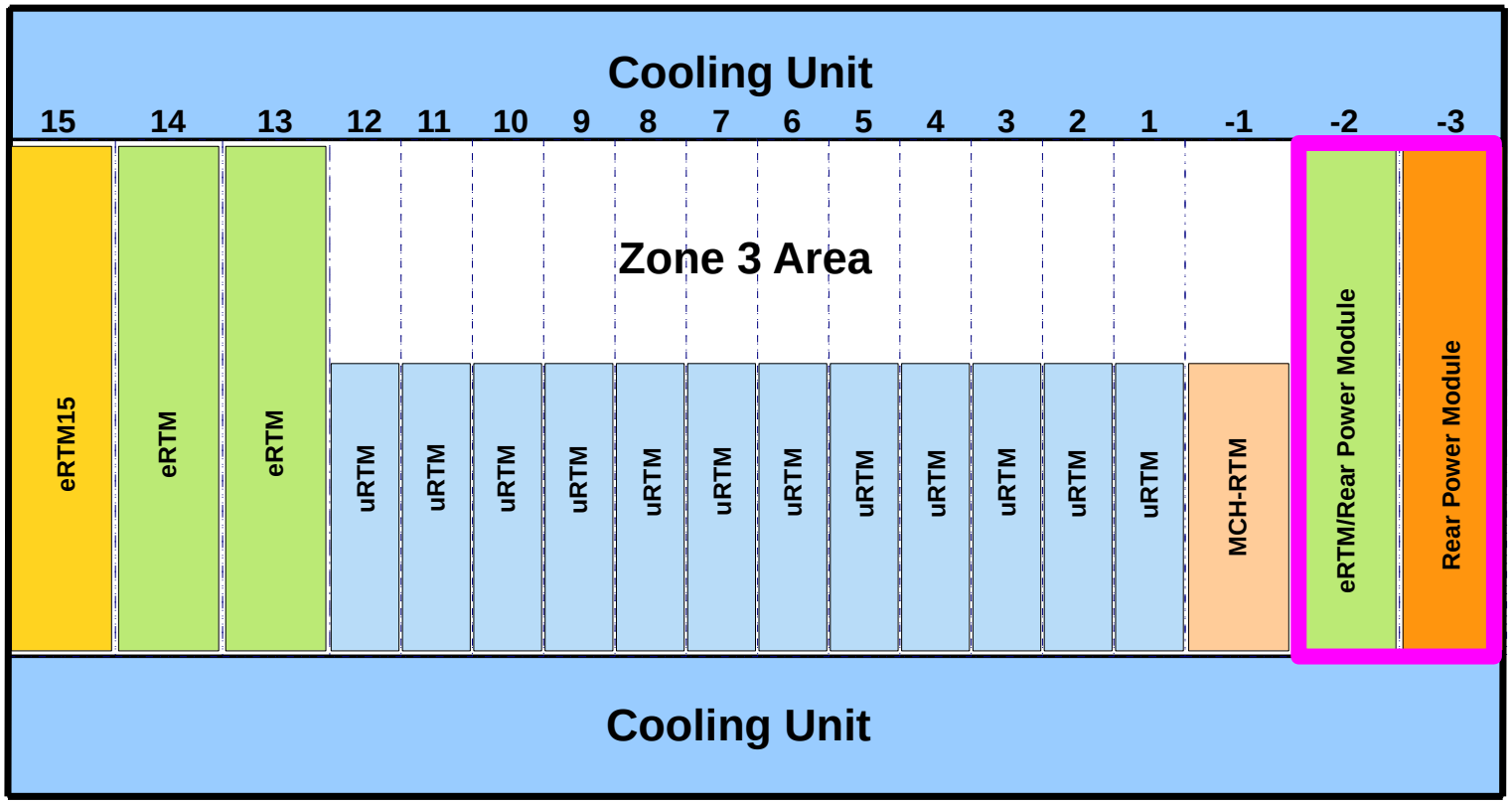
Up to 4 extended RTMs (eRTM)



# Slots, eRTMs and Rear Power Supply Modules

Rear View

1 or 2 Rear Power Supply Modules



# uRFB – Final Concept Highlights

- **Fully compatible to the standard**. No mechanical collision with standard RTM boards. Supported by crate manufacturers

- **Hot swap functionality for RF signals.** IPMI extension for uRFB worked out with N.A.T.

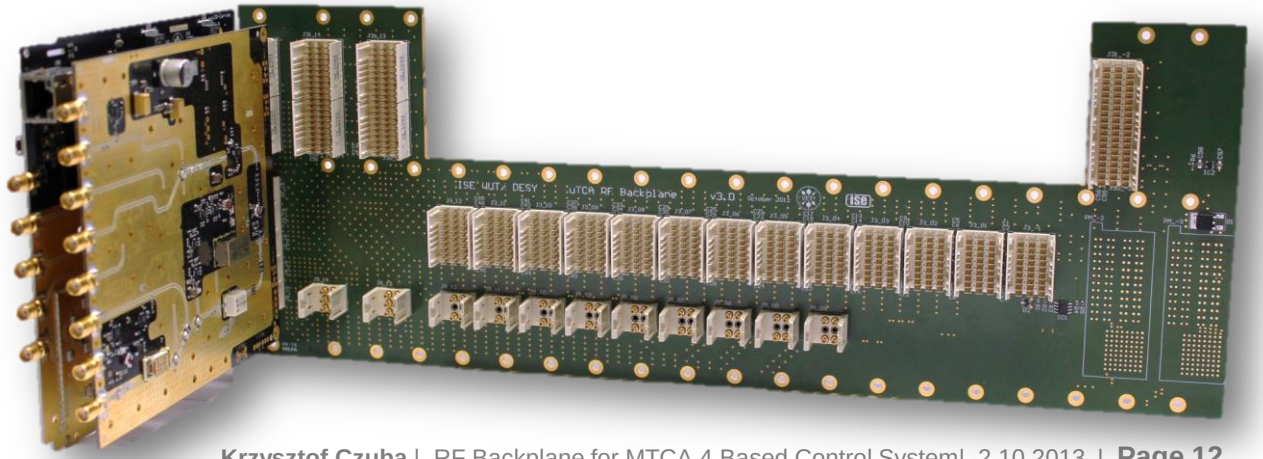
- uRFB fully passive. All intelligence in modules -> great flexibility for users

- Developed a concept of extended RTM (eRTM) boards

- Redundant high performance rear power supply for analog applications

# eRTMs

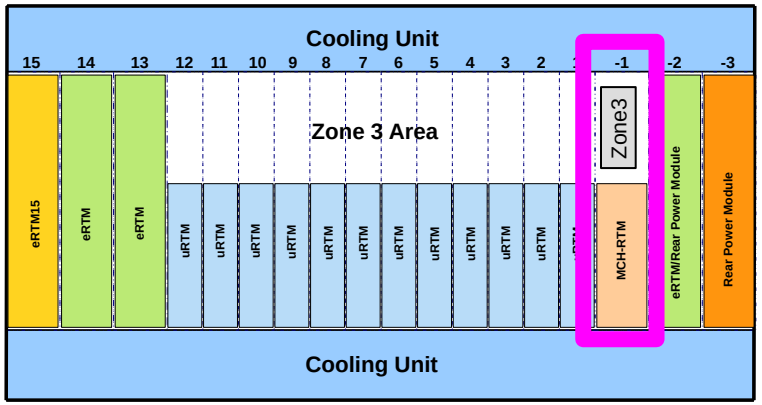
- Offer system designers additional space (note that eRTMs are wider (6HE) than uRTMs (4HE))
- Designers can use 2 or even 3 slots for one module if necessary
  - eRTMs can be used for applications requiring significant space for components like filters or precise temperature stabilization
- uRFB provides management, power supply and data links for eRTMs
- Slot 15 was assigned for RF signal entry. See uLOG poster by T. Rohlev as an example input board design



# uRFB Management and Power Supply

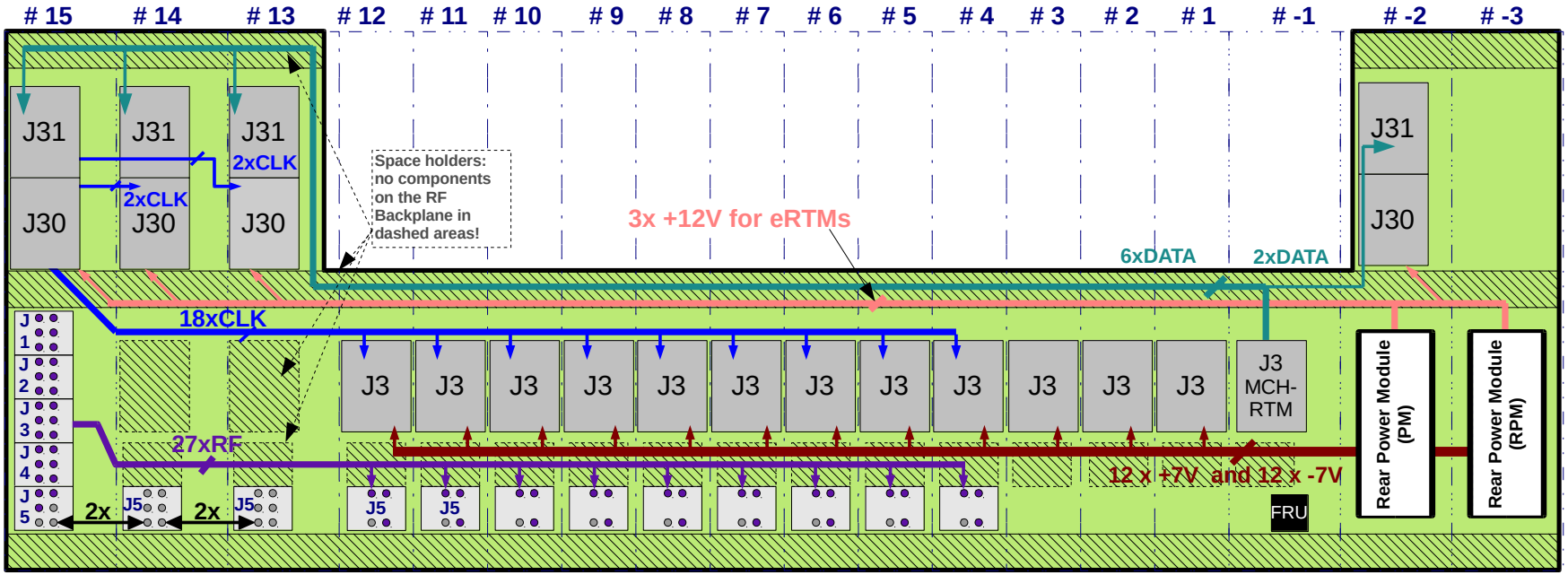
- An MCH-RTM board in slot #-1 will manage the uRFB
- Connected to MCH via Zone 3
- Standard (AMC) management „mirrored” to the RTM side will be used to reduce development cost and time

Rear View




- eRTM and uRTM FRUs will contain information about required connectivity and power supply
- Rear Power Module can supply 4 x +12V to all eRTMs and 12x +/- 7V to uRTMs
- uRTM designer can decide to use +/-7V from uRFB or standard _12V from AMC
- Economy use case: power supply for eRTM in slot #15 from MCH-RTM (no Rear PM) but limited to max 25W

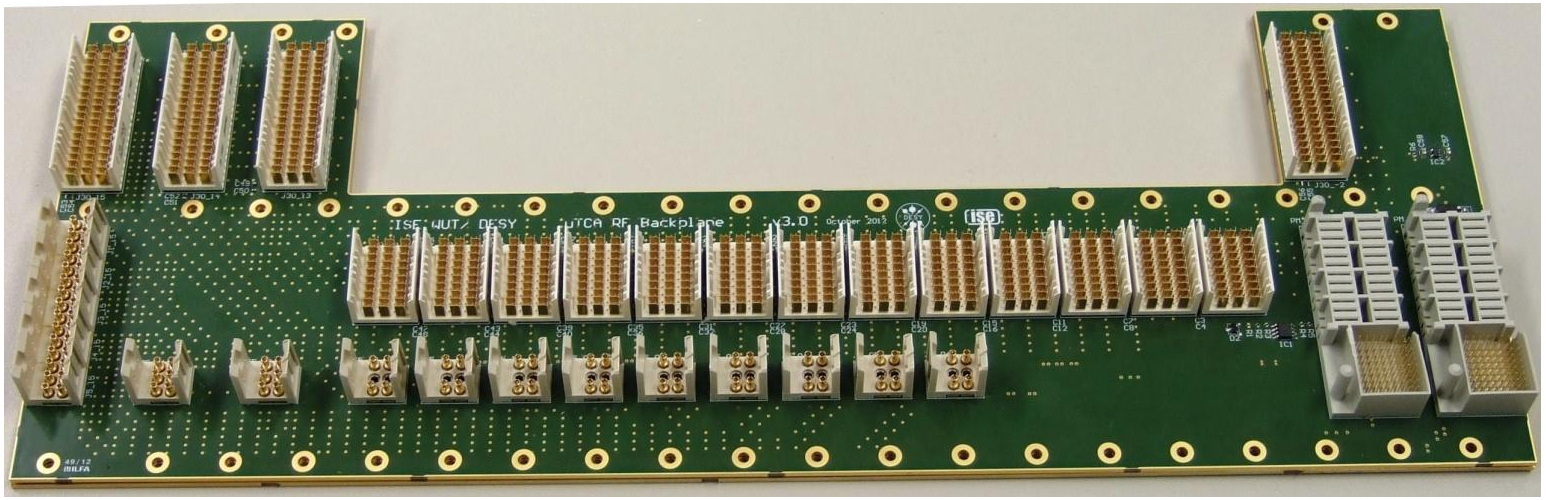
# Simplified Block Diagram of uRFB Designed for XFEL LLRF System



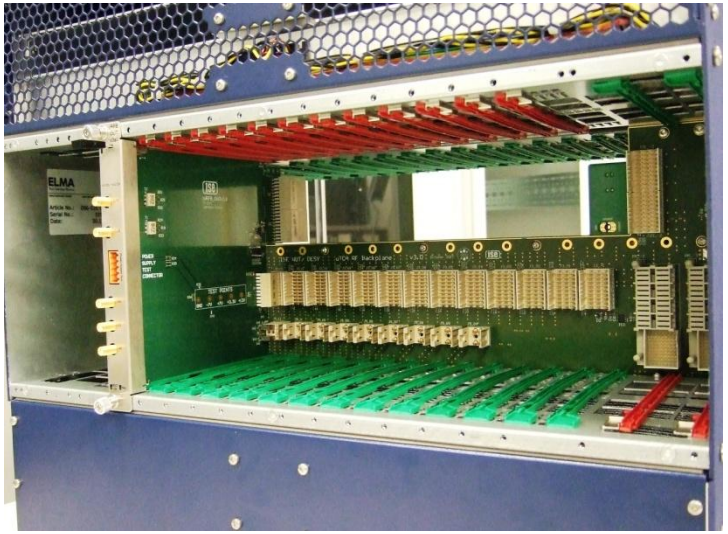

- 27 RF signals (optimized for 1.3 GHz but can work up to 6 GHz)
- Hot-swap for RF signals
- 22 CLK signals
- „Analog” power supply: +/-7 V for RTMs and +12 V for eRTMs
- Management and communication

# Project Status

# Project Status: Tested uRFB PCB Prototype and Fixed Crate Extensions

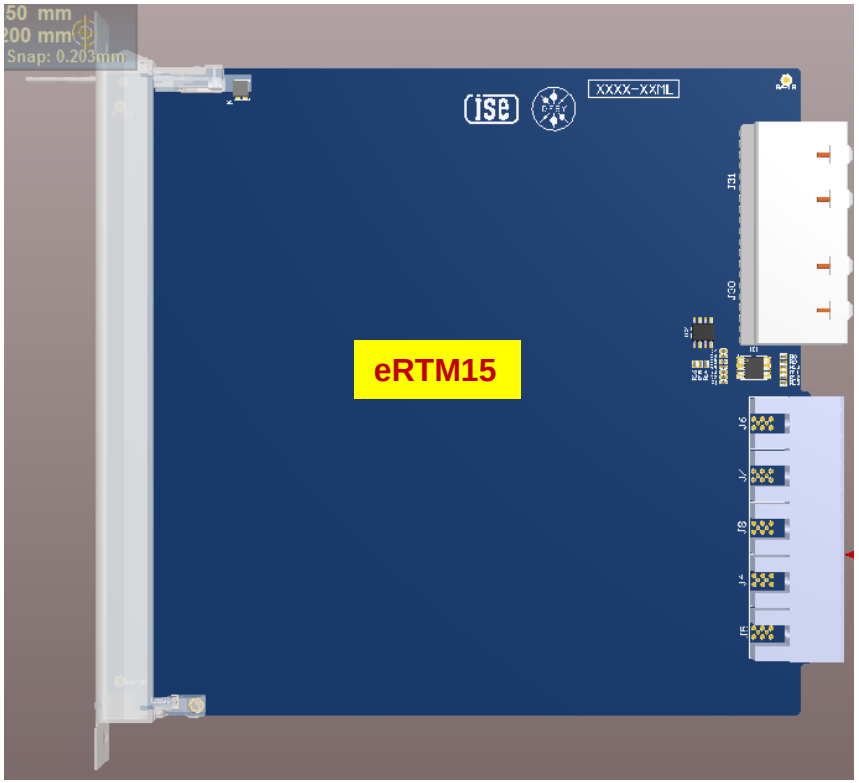


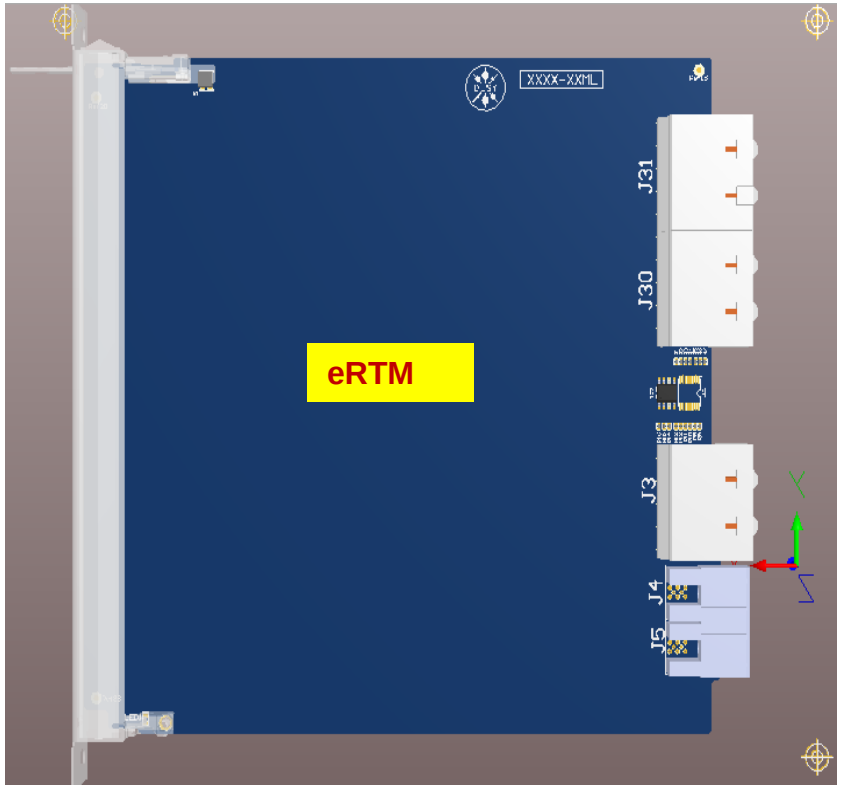

PCB Designer: T. Leśniak, K.Czuba, P. Kownacki




- Boards developed to test interconnections and prove feasibility of the uRFB concept
- Crate manufacturers worked out solutions for additional slots and cooling capacity

# Project Status: eRTM Templates

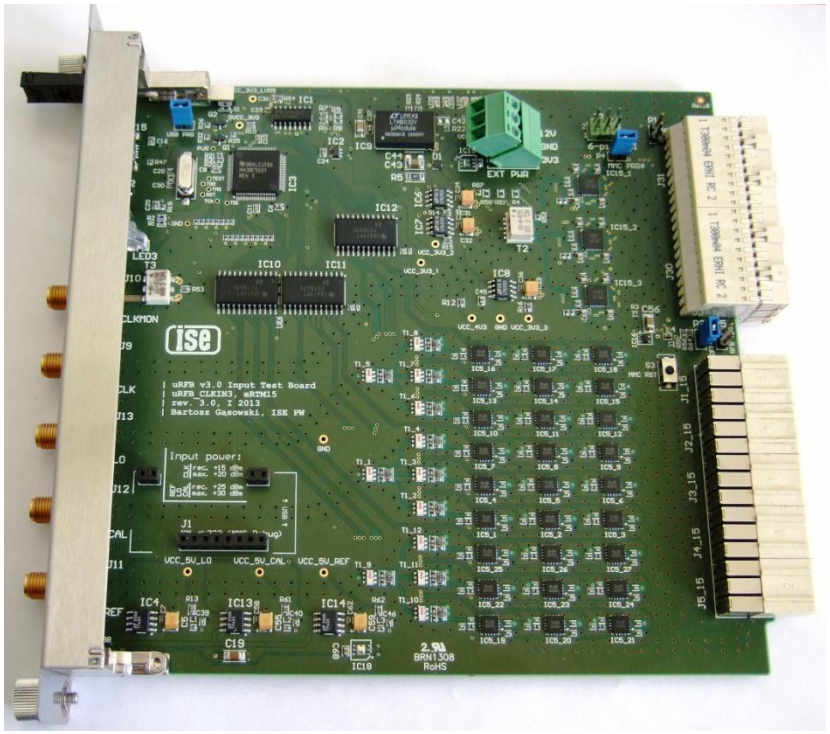



**Will be available on the MTCA webpage**

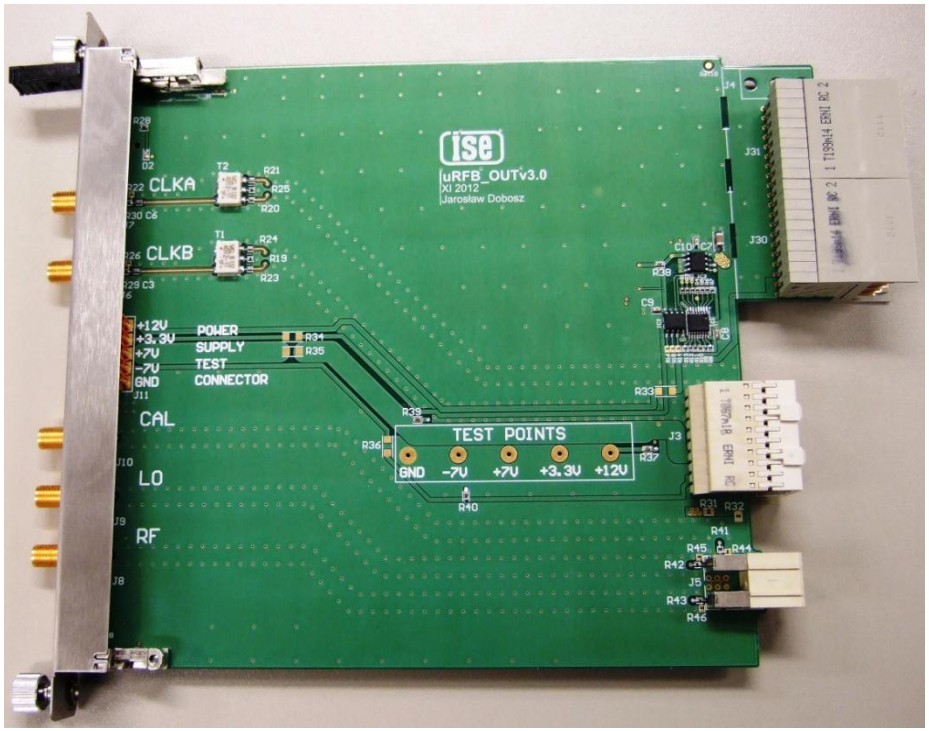
# Project Status: eRTM and uRTM Test Boards

## Input test board (eRTM15)




PCB Designer: B. Gąsowski

## Output test board (RTM)




PCB Designer: J. Dobosz

# Project Status: uRFB Measurements

- Developed automated teststand
- Measurements in laboratory and in the crate filled with digital boards
- No detectable signal spectrum degradation – in range 9kHz – 6 GHz (no spectral lines at level above instrument noise floor of -75 dBm)
- Excellent isolation from digital side of the MTCA crate

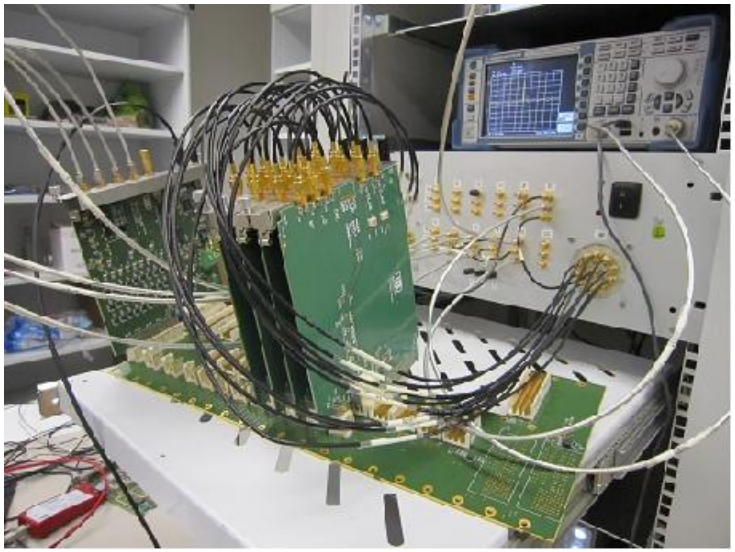


Table I: Measurement Results of The Attenuation and Reflection Coefficients of the uRFB at Frequency 1.300 GHz for REF and CAL and 1.354 GHz for LO Lines

| Slot | $A_{REF}$ [dB] | $\lvert\Gamma_{REF}\rvert$ [dB] | $A_{LO}$ [dB] | $\lvert\Gamma_{LO}\rvert$ [dB] | $A_{CAL}$ [dB] | $\lvert\Gamma_{CAL}\rvert$ [dB] |
|---|---|---|---|---|---|---|
| 4 | 3.4 | -16.2 | 3.5 | -16.5 | 3.1 | -18.5 |
| 5 | 2.8 | -15.4 | 3.3 | -16.8 | 4.3 | -18.2 |
| 6 | 3.3 | -15.6 | 4.7 | -17.1 | 3.2 | -19.0 |
| 7 | 2.3 | -15.4 | 2.6 | -16.2 | 2.6 | -17.9 |
| 8 | 2.1 | -15.2 | 2.9 | -16.7 | 4.1 | -17.6 |
| 9 | 3.4 | -15.1 | 3.4 | -16.7 | 3.3 | -18.3 |
| 10 | 1.5 | -15.4 | 2.3 | -16.7 | 2.0 | -18.0 |
| 11 | 1.4 | -15.5 | 2.5 | -16.8 | 1.9 | -18.4 |
| 12 | 1.9 | -15.2 | 1.2 | -16.7 | 2.6 | -18.4 |

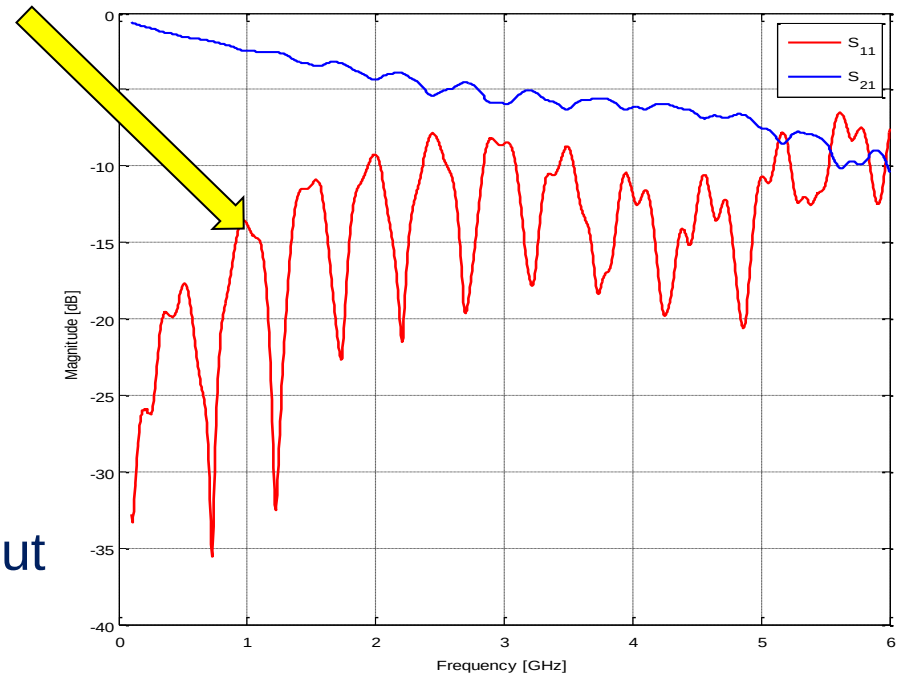
# Current Activities

# Current Activities: RF Performance Optimization for up to 6GHz

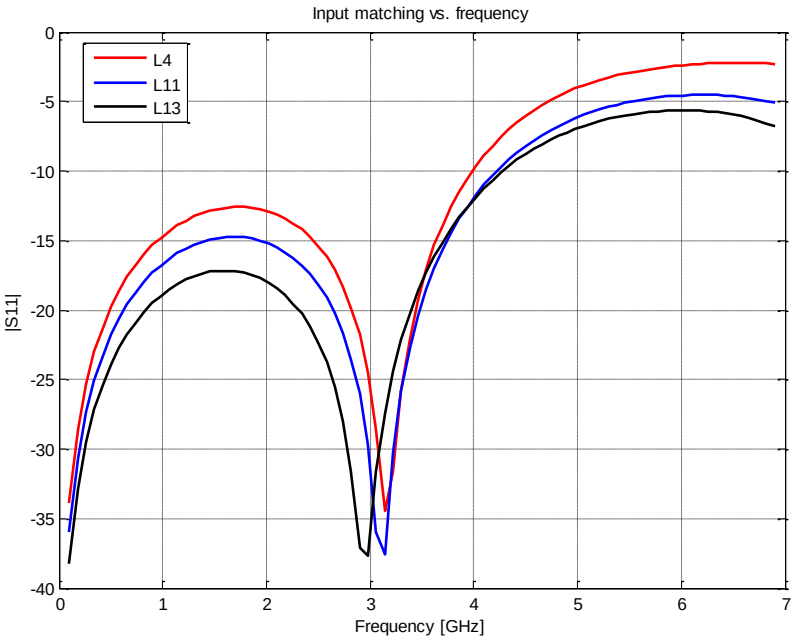
- **The HVF project requires operation in frequency range 0.1- 6GHz (so far PCB was optimized for 1.3 GHz)**

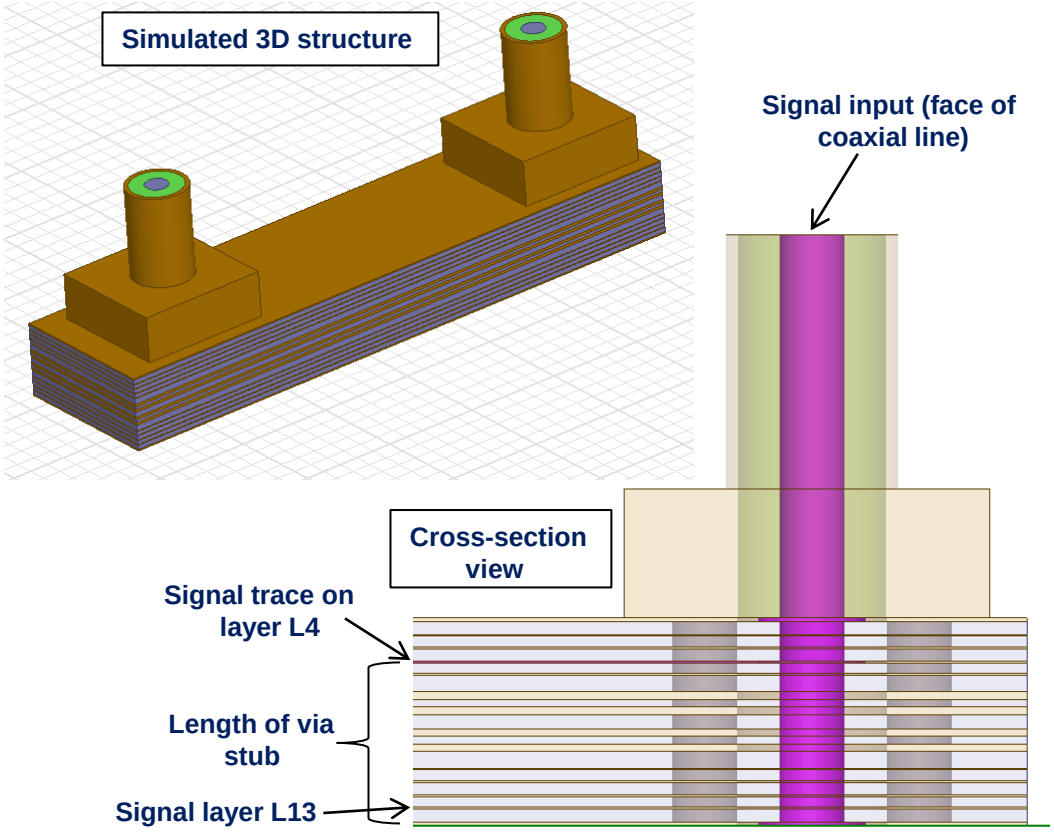
- Difficulties with precise calibration (lack of cal kit with multicoax connectors) -> special calibration boards under development
- Still good results up to ~2.5GHz
- Matching problems above 2.5GHz due to PCB layout around coax connector
- 3D EM simulations done to identify problem sources and optimize layout
- <u>New PCB version ready for manufacturing this week</u>

Measured RF loss and reflections of selected RF channel vs. frequency



# Example of 3D EM Simulations: Influence of a Via Stub




Courtesy of: T. Leśniak, Ł. Kowalczyk

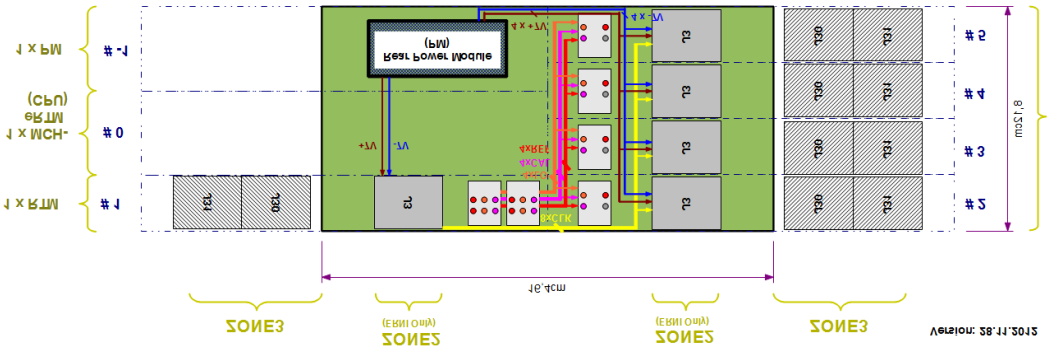
- **Simulations and optimization performed also for other issues of connector layout**
- **So far simulations well match measurement results**

# Current Activities: Management, Power Modules and Drifts

- The MCH-RTM (uRFB management) board is under development. Expected in Nov. 2013.
- Rear Power Modules under development. Expected by end of 2013
- RF signal phase drifts measurements: important for long term LLRF system performance
  - Set of test adapters and drift teststand are under development. Phase drifts will be characterized with temperature and humidity changes

# Future Plans

- <u>EMI tests:</u> investigation of uRFB influence on the MTCA crate performance.
- <u>Reliability tests</u>: after having the final design frozen (expected Q1 of 2014)
- <u>Industry licensing:</u> companies are interested to offer MTCA crates with uRFB option
- RF Backplane for small form factor crates



# Summary

- Compact solution integrated with the crate
- No collision with standard MTCA cards
- Reduces number of cable connections and improves reliability and maintainability
- Hot-swap for RF signals up to 6 GHz
- Allows using high-performance power supplies (managed) for RTMs
- eRTMs to increase number and size of modules
- Developed and tested successfully
- No significant signal spectrum and jitter degradation
- Management and power supply under development
- Extensive performance tests prepared

# Thank you for attention!